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Paul J. Kononoff

University of Nebraska-Lincoln, pkononoff2@unl.edu

S. K. Ivan

University of Maryland - College Park

W. Matzke

Matzke-Holtz-Nelson Dairy Consultants

R. J. Grant

Miner Institute

R. A. Stock

Cargill Incorporated

See next page for additional authors

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Authors

Paul J. Kononoff; S. K. Ivan; W. Matzke; R. J. Grant; R. A. Stock; and Terry J. Klopfenstein

Milk Production of Dairy Cows Fed Wet Corn Gluten Feed During the Dry Period and Lactation¹

P. J. Kononoff,^{*2} S. K. Ivan,^{*3} W. Matzke,^{*4} R. J. Grant,[†] R. A. Stock,[‡] and T. J. Klopfenstein^{*}

^{*}Department of Animal Science, University of Nebraska, Lincoln 68583-0908

[†]Miner Institute, Chazy, NY 12921

[‡]Cargill Incorporated, Blair, NE 68008

ABSTRACT

An experiment was conducted with 36 primiparous and 40 multiparous Holstein cows to examine the effects of feeding wet corn gluten feed (WCGF) on 305-d milk production, dry matter (DM) intake, body condition score (BCS), and health. The experimental treatments included: 1) control—WCGF not fed ($n = 27$); 2) WCGF-L—cows received diets containing WCGF (38% DM basis) during lactation ($n = 23$); and 3) WCGF-DL—cows received diets containing WCGF (38% DM basis) during the dry period and lactation ($n = 26$). During the dry period, cows consuming WCGF were observed to have a significant gain in BCS (0.07 ± 0.06) compared with a loss in BCS in cows fed the control diet (control = -0.11 ± 0.06 and WCGF-L = -0.04 ± 0.06). During lactation, there were no differences by treatment on BCS. Cows consuming WCGF during lactation consumed more feed compared with the control: 25.4, 23.8, and 21.2 ± 0.76 kg/d for WCGF-L, WCGF-DL, and the control, respectively. Milk production was higher for cows consuming WCGF: 35.0, 34.7, and 31.1 ± 2.1 kg/d for WCGF-L, WCGF-DL, and the control, respectively. No differences were found in either DM intake or actual milk yield between the WCGF-L and WCGF-DL treatments, indicating that prepartum diets did not influence lactational performance. The WCGF diets resulted in significant reductions in the concentration of milk fat (3.94, 3.74, and $4.15 \pm 0.08\%$ for WCGF-L, WCGF-DL, and the control, respectively), but because total milk yield was increased, there were no differences in total milk fat yield. In addition, 3.5% of fat-corrected milk tended to be affected by diet: 38.9, 36.3, and 34.7 ± 1.93 kg/d for

WCGF-L, WCGF-DL, and the control, respectively. The increasing effect of DM intake and milk yield in cows consuming WCGF resulted in a similar efficiency of 3.5% fat-corrected milk production for all treatments, averaging 1.5 ± 0.09 . Total protein yields were significantly higher for cows consuming WCGF diets during lactation: 1.15, 1.10, 1.00 ± 0.06 kg/d for WCGF-L, WCGF-DL, and the control, respectively. These results indicate that diets may be formulated to contain as much as 37.5% WCGF (DM basis).

Key words: lactation, corn gluten feed, dairy

INTRODUCTION

The recent growth of the US milling industries has provided an economic stimulus for domestic agriculture. This growth has also resulted in an increased availability of feed by-products, such as corn distiller's grains and corn gluten feed (Schingoethe et al., 1999). A by-product of the wet milling industry, wet corn gluten feed (WCGF) is largely composed of corn bran and steep liquor but may also contain varying amounts of distiller's solubles, germ meal, and kernel screenings (Macken et al., 2004). According to the NRC (2001) feed library, WCGF typically contains 24% CP, 30% of which is undegradable in the rumen. Corn gluten feed also contains approximately 35% NDF and low levels of lignin (2%), and is a source of highly digestible fiber that may supply energy to the lactating dairy cow. Because WCGF contains a relatively low concentration of rapidly fermentable carbohydrates such as starch, these feeds supply energy without increasing the risk of ruminal acidosis (Wickersham et al., 2004).

A number of investigators have evaluated the effects on dairy cattle performance of replacing forages and concentrates with WCGF. Armentano and Dentine (1988) substituted corn and soybean meal with WCGF in rations containing a high proportion of alfalfa silage. Results suggested that WCGF could be included at 36% of the ration DM without affecting intake, milk production, or composition. More recently, VanBaale et al. (2001) observed that when cows were fed diets containing 20% WCGF, they consumed more DM and

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²Corresponding author: pkononoff2@unl.edu

³Current address: Department of Animal and Avian Sciences, University of Maryland, College Park, MD 20742.

⁴Current address: Matzke-Holtz-Nelson Dairy Consultants, Oshkosh, WI 54904.

produced more milk than those consuming diets higher in alfalfa hay, corn silage, and corn grain. Observations in both of these studies were collected in short-term crossover designs. In a study conducted over 15 wk, Schroeder (2003) observed that inclusion of WCGF at 0, 15, 30, and 45% resulted in 3.5% FCM, increasing in a quadratic manner (26.1, 31.6, 29.5, 26.9 kg). In an additional study conducted over 9 wk, Boddugari et al. (2001) demonstrated that a wet corn milling product similar to WCGF may be effective in diets for lactating dairy cows. When used to replace the concentrate, the product could be included at 45% of the ration DM and at over 60% when used to replace corn and forage. In a feeding trial involving 30 cows, these investigators also reported that, on average, cows consumed less feed but produced over 5 kg more milk when the WCGF replaced 50% of the concentrate and 30% of the forage of the control diet. These results suggest that the optimal inclusion level depends on the feedstuffs being substituted for, as well as other ingredients contained in, the ration.

For a dairy cow, the transition period is marked by a decrease in intake despite the energetic demand required for the onset of lactation. During this time, the inclusion of fibrous by-product feedstuffs has been demonstrated to increase DM intake (Ordway et al., 2002), thereby meeting the nutrient demands of maternal and fetal tissues and also facilitating the transition from gestation to lactation (Hayirli et al., 2003). Based on previous studies, we hypothesized that feeding a diet containing WCGF throughout the entire dry period and the subsequent lactation period would result in increased DMI and milk production compared with a control diet not containing WCGF. The objectives of this study were to examine the effects of replacing a portion of the ground corn, forage, and soybean meal with WCGF in the ration of periparturient and postparturient dairy cows to evaluate its effect on full lactational performance, intake, and body condition.

MATERIALS AND METHODS

Diets, Animals, and Experimental Design

Over a 2-yr period, 36 primiparous and 40 multiparous Holstein cows were assigned to a completely randomized design and were blocked according to age (primiparous or multiparous) and expected date of calving. During the dry period, cows were grouped by experimental treatment and fed in a group setting. During lactation, cows were housed in individual stalls and milked at 0730 and 1930 h and were injected with bST (Posilac, Monsanto, St. Louis, MO) following the manufacturer's directions. Cows were fed ad libitum at 0800 h to allow for approximately 5% refusal. The

Table 1. Chemical composition of wet corn gluten feed (WCGF) and corn silage (DM basis)

Composition, %	WCGF		Corn silage	
	Mean	SD	Mean	SD
CP	25.6	0.55	9.5	0.52
Soluble CP, % of CP	50.7	2.94	59.6	3.00
NDF	33.6	1.87	41.9	2.50
ADF	10.0	1.36	25.5	1.76
Ether extract	3.53	0.27	3.1	0.30
NFC ¹	29.7	0.91	40.1	2.76
Ash	7.58	1.00	5.3	0.23
Ca	0.05	0.01	0.32	0.04
Mg	0.43	0.03	0.16	0.01
P	1.09	0.06	0.23	0.03
K	1.53	0.07	1.43	0.29

¹Calculated by difference $100 - (\% \text{ NDF} + \% \text{ CP} + \% \text{ fat} + \% \text{ ash})$.

experimental cows were cared for according to the guidelines stipulated by the University of Nebraska Animal Care Committee. At dry off, 77 cows were assigned to 1 of 3 treatments: 1) the control, in which no WCGF was fed during the dry period and lactation ($n = 27$); 2) a TMR containing WCGF during lactation only (**WCGF-L**; $n = 23$); or 3) a TMR containing WCGF during both the dry period and lactation (**WCGF-DL**; $n = 27$). The chemical compositions of WCGF and corn silage are listed in Table 1, and the prepartum and lactation diets are listed in Tables 2 and 3. Diets were formulated to maximize the inclusion of WCGF and replace ingredients that were high in fiber, protein, and energy. Formulation aims for the diets fed were to keep the concentration of CP similar and to ensure that the concentration of NDF and energy met or exceeded NRC (2001) recommendations. For diets fed during lactation, attempts were made to keep the concentration of bypass protein similar.

Experimental Measures and Sample Analysis

Samples of feeds were collected weekly and composited by weight monthly. Collected samples were immediately frozen (-20°C) and stored for further analysis. Samples were then dried at 60°C in a forced-air oven and ground (1-mm screen, Wiley mill; Arthur H. Thomas Co., Philadelphia, PA). Ground samples were also analyzed for DM (100°C oven for 24 h). Samples were analyzed for Kjeldahl nitrogen (AOAC, 1990), ether extract (AOAC, 1990), calcium and phosphorus (AOAC, 1990), and percent ash (AOAC, 1990). Both NDF (Van Soest et al., 2001) and ADF were analyzed using an Ankom fiber analyzer (Ankom Technology, Fairport, NY). Heat-stable α -amylase (A3306; Sigma Chemical Co., St. Louis, MO) was included in the NDF procedure (100 $\mu\text{L}/0.50$ g of sample). Body weight and

Table 2. Ingredient and chemical composition of early dry and close-up total mixed diets¹ (DM basis)

Diet	Early dry		Close-up	
	Control	WCGF	Control	WCGF
Ingredient, %				
Grass hay ²	31.7	28.0	28.5	26.1
Corn silage	45.6	40.1	41.1	37.4
Corn gluten feed	—	29.9	—	30.0
Ground corn	9.4	—	11.5	—
Soybean hulls	2.4	—	4.0	—
Limestone	0.72	0.89	1.0	1.2
Soybean meal, 48% CP	9.6	0.64	13.6	4.8
Salt	0.06	0.11	—	—
Sel-Plex 1000 ³	0.04	0.04	0.04	0.04
Mineral-vitamin premix ⁴	0.26	0.26	0.39	0.39
Composition, %				
DM	50.1	48.6	52.4	50.0
CP	14.0	14.0	15.3	15.4
Soluble CP, % of CP	24.4	39.1	22.7	36.5
Starch	24.3	20.1	25.1	19.4
NDF	46.6	49.7	43.9	49.2
ADF	31.8	24.6	24.5	23.7
Ether extract	2.84	2.70	2.79	2.63
NFC ⁵	29.0	25.4	31.0	24.8
Ash	7.92	8.24	7.15	8.08
Ca	0.55	0.56	0.65	0.63
Mg	0.19	0.27	0.20	0.28
P	0.27	0.45	0.29	0.47
K	1.57	1.54	1.57	1.62

¹Control treatment: ration containing no wet corn gluten feed (WCGF); WCGF: ration containing WCGF.

²Contained 12.1% CP, 36.4% soluble CP (% of CP), 37.8% ADF, 67.1% NDF, 4.3% lignin, 2.4% fat, and 12.7% ash.

³Dietary selenium supplement (Alltech, Inc., Nicholasville, KY).

⁴Formulated to contain 1.0% Ca, 0.50% P, 0.36% Mg, and 1.3% K, and to provide 120,000 IU/d of vitamin A, 24,000 IU/d of vitamin D, and 800 IU/d of vitamin E in the total ration.

⁵Calculated by the difference 100 – (% NDF + % CP + % fat + % ash).

BCS (scale of 1 to 5) were measured at 60 (dry) and 21 d (close-up) before expected calving, immediately after calving, and weekly during lactation (Table 4). The BCS was measured by a single trained individual and differed from that described by Wildman et al. (1982) in being reported to the quarter point. Milk production was measured daily and milk samples were collected monthly during the a.m. and p.m. milkings and were preserved using 2-bromo-2-nitropropane-1,3 diol. Daily DMI and milk yields were averaged weekly. Milk samples were analyzed for fat and true protein (AOAC, 1990) using a B2000 infrared analyzer (Bentley Instruments, Chaska, MN) by Heart of America DHIA (Manhattan, KS).

Statistical Analysis

Milk production, intake, BW, and BCS data were analyzed using the MIXED procedure of SAS, Version

Table 3. Ingredient and chemical composition of total mixed diets fed during lactation¹ (DM basis)

Diet	Control	WCGF
Ingredient, %		
Alfalfa haylage ²	17.8	10.4
Alfalfa hay ³	12.0	8.5
Corn silage	29.8	18.9
Corn gluten feed	—	37.9
Cottonseed	8.7	5.1
Ground corn	20.3	12.5
Limestone	0.8	1.68
Soy Pass ⁴	1.7	1.68
Magnesium oxide	0.10	—
Soybean meal, 48%	6.0	0.45
Blood meal	0.62	0.53
Tallow	0.67	0.74
Sodium bicarbonate	0.67	0.76
Salt	0.19	0.19
Sel-Plex 1000 ⁵	0.06	0.06
Vitamin premix ⁶	0.12	0.15
Mineral premix ⁷	0.04	0.04
Urea	0.08	—
Ca:P, 23:18%	0.37	—
Composition		
DM, %	51.2	54.4
CP, %	17.2	17.2
RUP, ⁸ % of CP	34.1	33.9
Soluble CP, % of CP	32.9	42.6
Starch, %	29.5	24.8
NDF, %	31.5	34.6
ADF, %	20.8	18.1
NE _L , ⁸ Mcal/kg	1.59	1.56
Ether extract, %	5.45	4.56
NFC, ⁹ %	37.4	34.1
Ash, %	8.32	9.26
Ca, %	0.92	0.95
Mg, %	0.29	0.36
P, %	0.38	0.59
K, %	1.46	1.44

¹Control: ration containing no amount of wet corn gluten feed (WCGF). WCGF: ration containing WCGF.

²Contained 22.0% CP, 64% soluble CP, 35% ADF, 47% NDF, 7.1% lignin, 2.5% fat, and 13.1% ash.

³Contained 24.1% CP, 26% soluble CP (% of CP), 33.2% ADF, 46.7% NDF, 7.6% lignin, 2.0% fat, 10.2% ash.

⁴Bypass protein supplement (LignoTech, Overland Park, KS).

⁵Dietary selenium supplement (Alltech, Inc., Nicholasville, KY).

⁶Formulated to supply approximately 120,000 IU/d vitamin A, 24,000 IU/d of vitamin D, and 800 IU/d of vitamin E in total ration.

⁷Formulated to contain 1.0% Ca, 0.50% P, 0.36% Mg, and 1.3% K.

⁸According to NRC (2001).

⁹Calculated by difference 100 – (% NDF + % CP + % fat + % ash).

9.1 (SAS Institute, 1999) according to the following model:

$$Y_{ijklm} = \mu + T_i + P_j + TP_{ij} + B_k + C_{ijkl} + W_m + TW_{im} + TPW_{ijm} + e_{ijklm} \quad [1]$$

where Y_{ijklm} is the dependent, continuous variable, μ is the overall mean; T_i is the fixed effect of the i th treatment ($i = 1, 2, 3$); P_j is the fixed effect of the j th

Table 4. Effects on BW and BCS of feeding wet corn gluten feed (WCGF) to Holstein cows from dry off through the following lactation

Effect	Treatment ¹				P value		
	Control	WCGF-L	WCGF-DL	SE ²	Diet	Parity	Diet × parity ³
n							
Primiparous	12	11	13				
Multiparous	15	12	13				
Total	27	23	26				
Dry ⁴							
BW, kg	673.3	694.6	657.4	19.1	0.30	<0.01	0.36
BCS	3.68	3.65	3.54	0.06	0.15	0.05	0.98
Close-up ⁵							
BW, kg	738.9	748.8	722.3	16.64	0.50	<0.01	0.42
BCS	3.74	3.71	3.73	0.08	0.91	0.02	0.15
Calving ⁶							
BW, kg	664.6	660.6	649.1	14.9	0.71	<0.01	0.23
BCS	3.58	3.59	3.63	0.05	0.68	0.20	0.55
Dry to close-up change ⁷							
BW, kg	59.0	54.1	62.1	9.0	0.73	0.22	0.41
BCS	0.04 ^a	0.06 ^{ab}	0.17 ^b	0.05	0.06	0.79	0.11
Dry to calving change ⁸							
BW, kg	-13.57	-32.96	-10.60	11.8	0.29	0.04	0.97
BCS	-0.11 ^a	-0.04 ^a	0.07 ^b	0.062	0.02	0.26	0.65
Lactation ⁹							
BW, kg	617.9	645.4	621.9	13.76	0.29	<0.01	0.71
BCS	3.33	3.36	3.34	0.04	0.84	0.20	0.52

^{a,b}Means in the same row with different superscripts differ ($P < 0.05$).

¹Control treatment: animals fed diets containing no WCGF; WCGF-L: animals fed a ration containing WCGF during lactation only; WCGF-DL: animals fed rations containing WCGF during both the dry period and lactation.

²Highest standard error (SE) of treatment means is shown.

³Diet × parity = diet by parity interaction.

⁴Dry period BW and BCS were obtained from every cow approximately 60 d prepartum.

⁵Close-up period BW and BCS were obtained from every cow approximately 21 d prepartum.

⁶Calving BW and BCS were obtained from every cow the day after calving.

⁷Change in BW and BCS is the difference between values at the dry period and prior to the close-up period.

⁸Change in BW and BCS is the difference between values at the dry period and subsequent calving.

⁹BW and BCS during lactation (1 – 305 DIM).

parity ($i = 1, \geq 2$); TP_{ij} is the fixed effect of the i th treatment by j th parity; B_k is the random effect of the k th year ($k = 1, 2$); C_{ijl} is the random effect of the l th cow within the i th treatment, within the j th parity, and within the k th year ($l = 1, \dots, nij$); W_m is the fixed effect of the m th week of the experiment ($m = 1, \dots, 43$); TW_{im} is the fixed effect of the i th treatment by the m th week of experimental interaction; TPW_{ijm} is the fixed effect of the i th treatment by the j th parity by the m th week of experimental interaction; and $eijklm$ is the residual error.

The 3.5% FCM production, milk fat, and milk protein content and yield data were analyzed using the MIXED procedure of SAS (Version 9.1; SAS Institute, 1999) according to the following model:

$$Y_{ijklm} = \mu + T_i + P_j + TP_{ij} + B_k + C_{ijl} + M_m + TM_{im} + TPM_{ijm} + eijklm \quad [2]$$

where Y_{ijklm} is the dependent, continuous variable; μ is the overall mean; T_i is the fixed effect of the i th treatment ($i = 1, 2, 3$); P_j is the fixed effect of the j th parity ($i = 1, \geq 2$); TP_{ij} is the fixed effect of the i th treatment by the j th parity; B_k is the random effect of the k th year ($k = 1, 2$); C_{ijl} is the random effect of the l th cow within the i th treatment, within the j th parity, and within the k th year ($l = 1, \dots, nij$); M_m is the fixed effect of the m th test month experiment ($m = 1, \dots, 43$); TM_{im} is the fixed effect of the i th treatment by the m th test month of experimental interaction; TPM_{ijm} is the fixed effect of the i th treatment by the j th parity

by the m th test month of experimental interaction; and $eijklm$ is the residual error.

In the preceding models, the random effect of cow within-treatment subclasses was used as the error term for the effect of treatments. Residual errors [which are errors within cow across time and represent error from repeated measurements in the experimental unit (cow)] were modeled using a compound symmetry covariance structure. Overall treatment differences were examined using least squares means (LSMEANS). Significance was declared at $P \leq 0.05$. A trend in the data was declared at $0.05 < P \leq 0.10$ and was used only for interpretation of the data. The DIFF option was used to test treatment differences among LSMEANS, and the SLICE option was used to analyze differences among weekly treatment means.

The lactation curve for each cow was described using the Wood incomplete gamma function: $y_t = at^be^{-ct}$ (Wood, 1967), where y_t is milk production at time t ; a , b , and c are parameters describing curve shape; and e is the base of the natural logarithm. Estimated parameters were obtained using the NLIN procedure of SAS (Saxton, 2004). Parameter a is milk production at the beginning of lactation; b is the slope before peak (prepeak) milk production; and c is the slope after peak (postpeak) milk production. According to the Wood model, lactation reaches a maximum at time $t = b/c$, with an expected production of $a(b/c)^b \exp^{-b}$. Persistence was estimated as $s = -(b + 1)/c$. The effects of diet, parity, and parity \times diet interaction on each Wood parameter and estimate were tested using the following model:

$$Y_{ijkl} = \mu + T_i + P_j + TP_{ij} + B_k + C_{ijl} + eijkl \quad [3]$$

where Y_{ijklm} is the dependent variable, μ is the overall mean; T_i is the fixed effect of the i th treatment ($i = 1, 2, 3$); P_j is the fixed effect of the j th parity ($j = 1, \geq 2$); TP_{ij} is the fixed effect of the i th treatment by the j th parity; B_k is the random effect of the k th year ($k = 1, 2$); C_{ijl} is the random effect of the l th cow within the i th treatment, within the j th parity, and within the k th year ($l = 1, \dots, n_{ijk}$); and $eijkl$ is the residual error.

The effect of dietary treatment on the categorical responses related to health was tested using the GENMOD procedure of SAS (SAS Institute, 1999). The statistical model included the fixed effects of diet, parity, and year.

RESULTS AND DISCUSSION

Ration Composition

The WCGF contained 40% moisture and contained 25.6% CP, 33.6% NDF, 10.0% ADF, 29.7% NFC, and

3.53% ether extract (DM basis; Table 1). The control diets fed during the early dry and close-up periods contained 77 and 67% forage, respectively. Both the early dry and close-up treatment diets were formulated to contain 30% WCGF (DM basis) by replacing ground corn, soybean hulls, and a portion of the soybean meal (Table 2). The chemical compositions of the control and treatment diets fed during the early dry period were similar (Table 2), containing approximately 14% CP, but the WCGF diet contained approximately 4% less starch, 3% more NDF, and 0.18% more phosphorus (DM basis). As in the early dry period, diets fed during the close-up period contained similar amounts of protein (15%), but the WCGF diet contained approximately 6% less starch, 5% more NDF, and 0.18% more phosphorus (DM basis). The control diets fed during lactation contained 60% forage, which was 22% more forage than the WCGF treatment diet. The WCGF treatment diet was formulated to contain 40% WCGF (DM basis) by reducing the amount of forage by 22 percentage units and the amount of concentrate by 17 percentage units (Table 3). The diet fed during lactation contained similar amounts of protein (17%), but the WCGF diet contained approximately 5% less starch, 3% more NDF, and 0.21% more phosphorus (DM basis).

BW and BCS

Body weight and BCS were measured at 60 (dry) and 21 d (close-up) before expected calving as well as immediately after calving (Table 4). Neither BW nor BCS were affected by dietary treatment during these periods. However, the change in BCS between 60 and 21 d before expected calving tended ($P = 0.06$) to be affected by dietary treatment. Cows fed a diet containing the WCGF during the dry and close-up periods tended to have a greater increase in BCS (0.17 ± 0.05), compared with those fed the control diet during this period (control = 0.04 ± 0.05 and WCGF-L = 0.06 ± 0.05). Although the change in BW was not affected, numerical differences in the BW change support the same trend as those observed in the BCS change. Cows consuming the WCGF during the far-off dry and close-up periods had the highest numerical increase in BW (62.1 vs. 59.0 and 54.1 ± 9.0 kg for WCGF-DL, control, and WCGF-L, respectively). Upon calving, cows consuming WCGF through the early dry and close-up periods were observed to have a slight gain in BCS (0.07 ± 0.06). This was significantly higher than that of cows consuming the control diet, who experienced a slight loss in BCS: -0.11 and -0.04 ± 0.06 for the control and WCGF-L treatments, respectively. Current industry recommendations state that cows should calve with a

BCS of 3.25 to 3.50 and should neither gain nor lose body condition during the dry period (Contreras et al., 2004). In the current experiment, all cows had a slight gain in BCS during the far-off dry period, but cows consuming the control diet during the close-up period had a slight loss. The loss of BCS during the close-up dry period has been reported by others (Domecq et al., 1997) and is usually associated with inadequate energy intake (Dann et al., 2005; Smith et al., 2005) but does not always affect milk yield of the subsequent lactation (Ferguson, 1992). Although only a modest effect was observed, the increase in BCS in the current experiment may be an indication that diets containing WCGF may have resulted in an increase in DMI and, as a result, an improved nutritional status. The intake response in cows fed nonforage fiber sources during the prepartum feeding has been described by Pickett et al. (2003). In that experiment, cows consuming nonforage fiber sources were also observed to have a decrease in plasma NEFA—a reflection of less fat being mobilized from body fat reserves (Drackley, 1999). Because neither DMI nor NEFA were measured during the dry period, it is difficult to explain why feeding WCGF resulted in the increase in BCS during this time. However, results suggest that partial substitution of both concentrate and forage sources provided some benefit to improved body condition when fed during the dry period, possibly due to higher energy intakes.

Subsequent to calving, BW and BCS were measured weekly. Mean BCS is listed in Table 4, and weekly estimates are illustrated in Figure 1. Although feeding WCGF during the dry period resulted in improvements in the BCS, there were no treatment differences in BCS during wk 1 of lactation, which averaged 3.55 ± 0.07 across treatments. This observation indicates that cows calved within the recommended range of BCS. There were no differences due to treatment on postpartum BW and BCS, which averaged 627.5 ± 13.8 and 3.34 ± 0.04 kg across treatments and during lactation (Table 4, Figure 1). This is similar to the observations of Boddugari et al. (2001), who observed no differences in BW and BCS when WCGF was fed in place of both fiber and concentrate. Although there were no treatment differences, the lowest BCS for all treatments was between wk 7 and 10. This result is 3 wk later than reported by Domecq et al. (1997) but is similar to the results observed by Waltner et al. (1993). Because body condition at the end of lactation is an accurate indicator of the energy status of a cow (Dechow et al., 2004), BCS was evaluated during the last week of lactation. Although cows consuming the control diet had the lowest BCS (3.47 ± 0.06), this was not significantly different from either of the remaining

treatments (3.54 ± 0.06 for both WCGF-L and WCGF-DL).

Intake, Milk Yield, FCM, and Milk Components

There were no differences in either DMI or actual milk yield between WCGF-L and WCGF-DL treatments, indicating that prepartum diets did not influence lactational performance. Cows consuming rations containing the WCGF during lactation consumed significantly more feed compared with the control (Table 5, Figure 2). Actual milk production was significantly higher for cows consuming the WCGF (Table 5, Figure 3). The paired increase in DMI and milk yield resulted in a similar efficiency of milk production, with 3.5% FCM averaging 1.5 across treatments. The increase in DMI for cows consuming WCGF is in contrast to the observations of Boddugari et al. (2001). These investigators observed that partial replacement of the WCGF for concentrate and forage, or 40% of the diet DM, resulted in cows consuming less feed but producing more than 5 kg more milk. It is difficult to speculate on the reasons for the discrepancy between these studies, especially considering the similarity in diets. Nevertheless, the increase in DMI is not surprising, given that intake is influenced by feed particle size and digesta passage rate (Beauchemin and Yang, 2005), which has been demonstrated to increase in diets containing WCGF (Boddugari et al., 2001).

The Wood model, which uses an incomplete gamma function, was used to describe the lactation curve of each individual cow. The shapes of the lactation curves were similar across treatments, as no differences were found on parameters *a* (initial milk yield), *b* (slope prepeak), and *c* (slope postpeak; see Table 6). Time to peak milk production was similar across treatments, averaging 20 ± 2.7 wk. Peak milk production tended to be affected by dietary treatment. Specifically, peak milk production was lowest in cows consuming the control diet (36.2 ± 2.27 kg) and higher in cows consuming the WCGF diet during lactation (40.1 ± 2.27 kg) and during the dry period and lactation (39.8 ± 2.27 kg). Although feeding WCGF during the dry period resulted in an increase in BCS, there were no differences in milk production during early lactation. Specifically, the slope of the lactation curve prepeak (*b*) and the level of peak milk were similar for WCGF-L and WCGF-DL. This indicates that although cows were fed different diets during the dry period, feeding WCGF during this time did not result in differences in milk production during early lactation. Persistence was similar across treatments, averaging 5.32; this response is consistent with previous findings (Boddugari et al., 2001). In an experiment conducted over 15

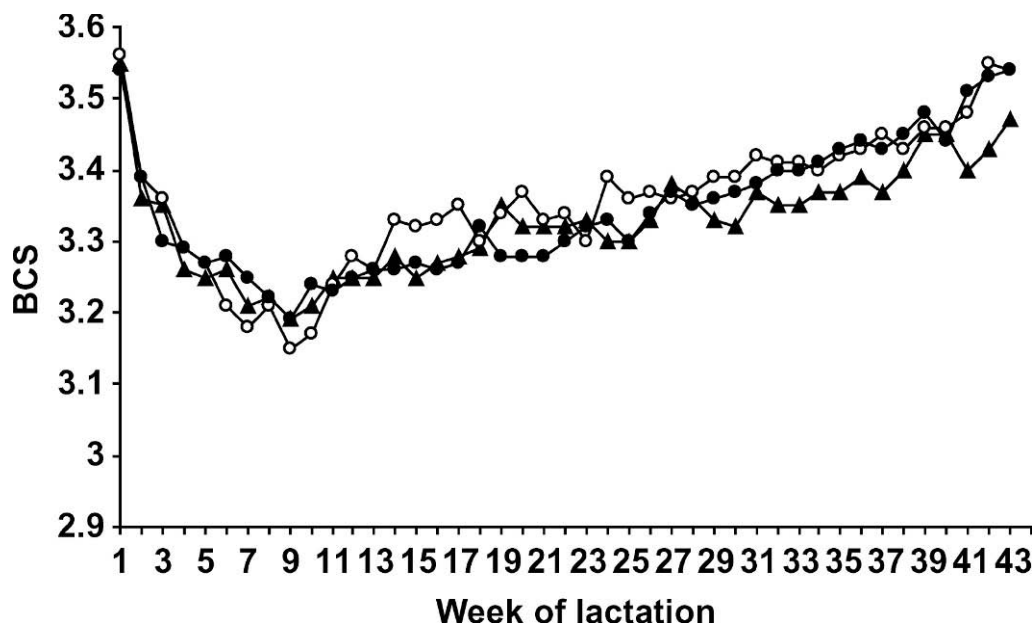


Figure 1. Body condition score of cows fed (\blacktriangle) the control diet [no wet corn gluten feed (WCGF)], (\circ) WCGF during lactation only (WCGF-L), and (\bullet) WCGF during both the dry period and lactation (WCGF-DL). Means for the respective treatments over the entire lactation were 3.33, 3.36, and 3.34 kg/d (SE 0.04, $P = 0.84$); no effect of parity was observed ($P = 0.20$), and no interaction between diet and parity was observed ($P = 0.52$).

wk of lactation, Schroeder (2003) observed a quadratic response on DMI and FCM yield when WCGF was used to replace forage and barley grain at 15, 30, and 45% of the diet DM. In this experiment, both intake and milk yield increased when WCGF was fed at 15 and 30% of the diet DM, but when diets contained 45%, no differences were observed when compared with the control. The increase in milk yield reported previously (Boddugari et al., 2001) was attributed to the improvement in nutrient digestibility. Unfortunately, data from the current study do not allow inferences regard-

ing rumen fermentation or total diet digestibility and effects on milk yield, but this reason remains plausible. Nevertheless, diets containing WCGF were consumed in the greatest amounts, thus supplying more energy for milk production. This result supports the observations of others who evaluated the effects of feeding WCGF to lactating dairy cows (VanBaale et al., 2001).

Inclusion of the WCGF also resulted in reducing the concentration of milk fat; however, since total milk yield was increased, no differences were observed in

Table 5. Effects of feeding wet corn gluten feed (WCGF) to Holstein cows from dry off through lactation

Effect	Treatment ¹			SE ²	P value		
	Control	WCGF-L	WCGF-DL		Diet	Parity	Diet \times parity ³
DMI, kg/d	21.2 ^b	25.4 ^a	23.8 ^a	0.8	<0.01	<0.01	0.62
Milk yield, kg/d	31.1 ^b	35.0 ^a	34.7 ^a	2.1	0.03	<0.01	0.27
3.5% FCM, kg/d	34.7 ^b	38.9 ^a	36.3 ^{ab}	1.9	0.10	0.04	0.58
Fat, %	4.15 ^a	3.94 ^{ab}	3.74 ^b	0.08	<0.01	0.33	0.47
Fat yield, kg/d	1.30	1.43	1.30	0.07	0.14	0.08	0.78
Protein, %	3.19	3.17	3.16	0.04	0.80	0.66	0.39
Protein yield, kg/d	1.00 ^b	1.15 ^a	1.10 ^{ab}	0.06	0.03	0.04	0.64
Milk/DMI, kg/kg	1.50	1.43	1.55	0.09	0.39	0.22	0.26

^{a,b}Means in the same row with different superscripts differ ($P < 0.05$).

¹Control treatment: animals fed diets containing no WCGF; WCGF-L: animals fed a ration containing WCGF during lactation only; WCGF-DL: animals fed rations containing WCGF during both the dry period and lactation.

²Highest standard error (SE) of treatment means is shown.

³Diet \times parity = diet by parity interaction.

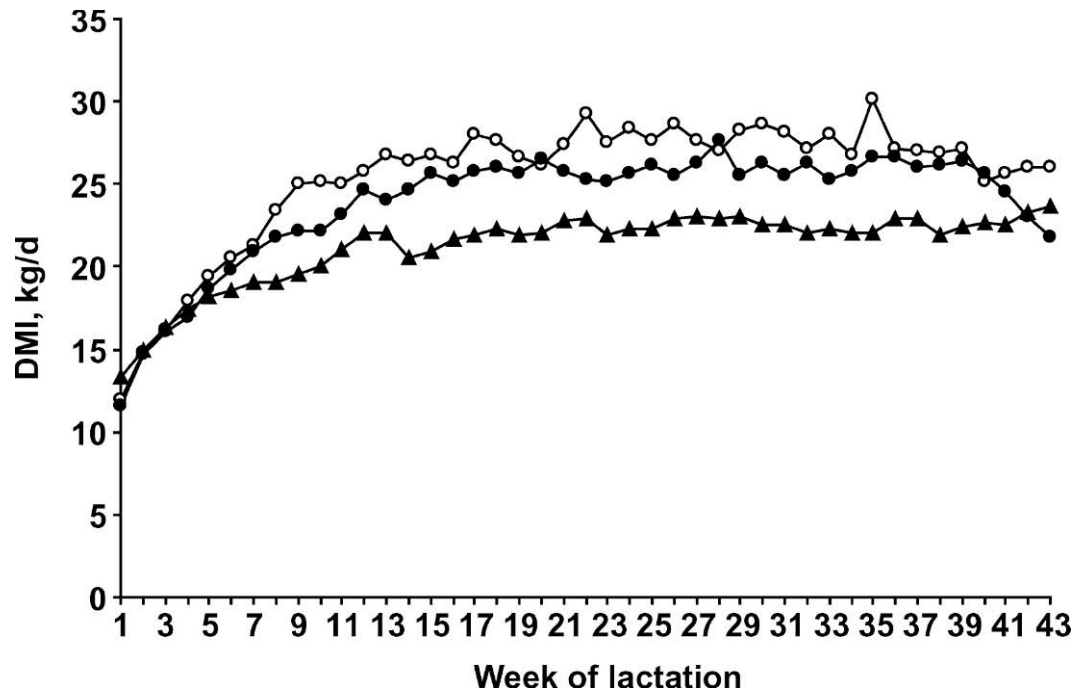


Figure 2. Dry matter intake of cows fed (▲) the control diet [no wet corn gluten feed (WCGF)], (○) WCGF during lactation only (WCGF-L), and (●) WCGF during both the dry period and lactation (WCGF-DL). Means for the respective treatments over the entire lactation were 21.1, 25.4, and 23.8 kg/d (SE = 0.73, $P < 0.01$); a significant effect of parity was observed ($P < 0.01$), but no interaction between diet and parity was observed ($P = 0.62$).

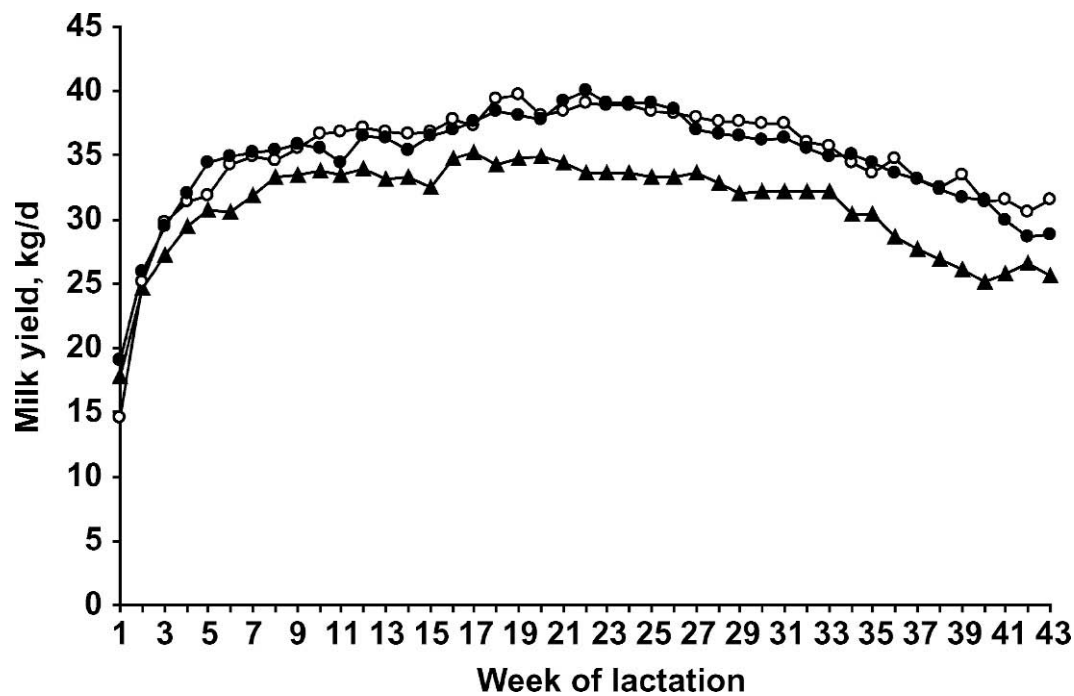


Figure 3. Lactation curves of cows fed (▲) the control diet [no wet corn gluten feed (WCGF)], (○) WCGF during lactation only (WCGF-L), and (●) WCGF during both the dry period and lactation (WCGF-DL). Means for the respective treatments over the entire lactation were 31.1, 35.0, and 34.7 kg/d (SE = 2.1, $P = 0.03$); a significant effect of parity was observed ($P < 0.01$), but no interaction between diet and parity was observed ($P = 0.27$).

Table 6. Effects of feeding wet corn gluten feed (WCGF) to Holstein cows on time to peak production, peak milk production, and persistence

Parameter	Treatment ¹				P value		
	Control	WCGF-L	WCGF-DL	SE ²	Diet	Parity	Diet × parity ³
a, initial milk yield, kg	18.5	19.3	20.5	2.8	0.60	<0.01	0.45
b, slope prepeak, kg/wk	0.44	0.42	0.39	0.05	0.78	0.63	0.78
c, slope postpeak, kg/wk	0.028	0.032	0.023	0.005	0.29	0.29	0.29
Time to peak, ⁴ wk	19.9	20.9	19.3	2.7	0.91	0.02	0.22
Peak milk, ⁵ kg	36.2 ^b	40.1 ^a	39.8 ^{ab}	2.3	0.08	<0.01	0.05
Persistence ⁶	5.35	5.27	5.35	0.17	0.91	<0.01	0.14

^{a,b}Means in the same row with different superscripts differ ($P < 0.05$).

¹Control treatment: animals fed diets containing no WCGF; WCGF-L: animals fed a ration containing WCGF during lactation only; WCGF-DL: animals fed rations containing WCGF during both the dry period and lactation.

²Highest standard error (SE) of treatment means is shown.

³Diet × parity = diet by parity interaction.

⁴Time, $t = b/c$.

⁵Expected peak production = $a(b/c)^b \exp^{-b}$.

⁶Persistence = $-(b + 1) \ln c$.

total milk fat yield. These findings are in contrast with those of Boddugari et al. (2001) but are similar to those of VanBaale et al. (2001). Differences in the concentration of milk protein were not observed; however, since including the WCGF increased total milk yield, total protein yield was significantly higher for cows consuming the WCGF during lactation. These results are consistent with those reported by Boddugari et al. (2001) and VanBaale et al. (2001), in which milk protein yield was increased when cows were fed the WCGF. This response is possibly due to the higher feed intakes of cows consuming WCGF, as energy intake is positively correlated with milk protein synthesis (Grieve et al., 1986). Even though the increase in DMI was associated with an increase in milk production, no effect was

observed on BCS. Because lipid metabolism of body reserves is known to make up a substantial contribution to the energetic cost of milk production (Friggens et al., 2004), these results indicate that the increase in milk yield was supported by an increase in DMI and did not result in an excessive depletion of energy reserves.

Health and Reproduction Records

Cow health and reproduction records are listed in Table 7. Compared with other studies evaluating health and reproduction (Windig et al., 2005), the current study contained a small number of animals and should be interpreted with caution. Table 7 lists the

Table 7. Effects on health disorders of feeding wet corn gluten feed (WCGF) to Holstein cows from dry off through lactation

Disorder	Treatment ¹			P value	
	Control	WCGF-L	WCGF-DL	Diet	Parity
No. of animals	27	23	26		
Displaced abomasum	1	5	3	0.13	0.11
Metabolic disorder ²	1	1	1	0.99	0.81
Mastitis	6	10	9	0.23	0.19
Foot disorder ³	7	5	8	0.71	0.39
Respiratory	0	1	2	0.21	0.69
Services per conception ⁴	2.1	1.8	2.7	0.87	0.82
Number of days open ⁵	154.1	161.6	209.6	0.89	0.93

¹Control treatment: animals fed diets containing no WCGF; WCGF-L: animals fed a ration containing WCGF during lactation only; WCGF-DL: animals fed rations containing WCGF during both the dry period and lactation.

²Includes parturient paresis and hypocalcemia.

³Includes toe abscesses, toe ulcers, and hoof rot.

⁴Standard error of treatment means = 22.8.

⁵Standard error of treatment means = 0.82.

number of animals diagnosed with displaced abomasums, metabolic disorders, mastitis, foot disorders, or respiratory disorders. All observations of displaced abomasums occurred in cows early in lactation: control = 31 DIM, WCGF-L = 15 + 10 DIM, and WCGF-DL = 10 + 3 DIM. Table 7 also lists the number of services per conception and total days open by dietary treatment. No significant effects of dietary treatment were observed on any health or reproductive measure. Further research should be conducted with more animals and should be designed to evaluate the effects on these measures of feeding WCGF.

CONCLUSIONS

When observed over a full lactation, cows that were fed diets that contained 40% WCGF (DM basis) increased milk and protein yield. This effect was not dependent on animals receiving WCGF during the dry period. No differences in reproductive or health parameters were observed. It appeared that the increase in milk yield was due to an increase in DMI, which resulted in higher peak milk yields.

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